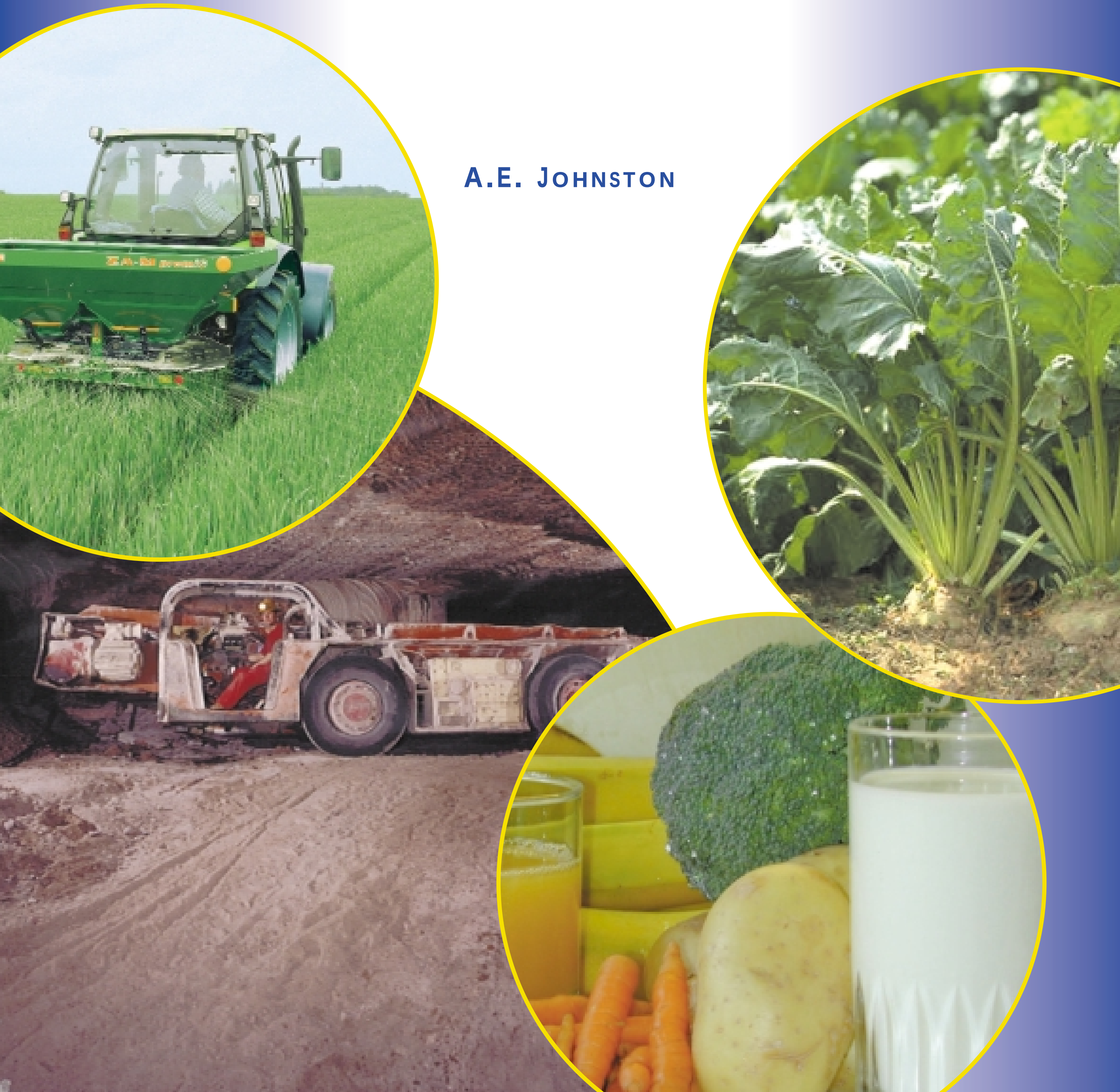
European Fertilizer Manufacturers Association

UNDERSTANDING POTASSIUM AND ITS USE IN AGRICULTURE

A.E. JOHNSTON



The plants grown in our diverse European landscape need a variety of nutrients. One of the essential nutrients is potassium.
'Understanding Potassium and its Use in Agriculture' explains the importance of potassium in plant nutrition and the diet of humans and animals, and describes the role of potassium based fertilizers in European agriculture.

Published by

European Fertilizer Manufacturers Association

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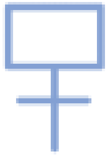
Potassium was first isolated in 1807 by Sir Humphrey Davy. It is a soft, silver white metal that reacts so violently with water that the metal does not occur in nature. The chemical symbol for the element, K, derives from kalium, the Latin version of the Arabic word for alkali. In agriculture, potassium is often referred to as potash. This name derives from the ancient practice of obtaining potassium salts by burning wood, extracting the ash with water and evaporating the resulting solution in iron pots – hence "pot-ashes". The resulting solid would be a mixture of potassium salts, mainly potassium carbonate, chloride and sulphate.

K

Chemical symbol for potassium



Alchemist symbol for potassium.

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Acknowledgements, Sources and References

Edited by Jackie Burton (EFMA) with scientific assistance from John Hollies (PDA), Adolf Krauss (IPI), Ingrid Steén (Kemira Agro Oy), International Fertilizer Industry Association – IFA.

Pictures from
Amazone, BASF AG, Cleveland Potash, EFMA, Hydro Agri, Institute of Grassland and Environmental Research (IGER), Kemira, K+S Aktiengesellschaft, Lemken, Macaulay Institute, Potash Development Association (PDA), and Rothamsted Research.

Introduction

As a major constituent within all living cells, potassium is an essential nutrient and is required in large amounts by both plants, animals and humans. Humans obtain the majority of their potassium either directly from plants or indirectly through the animal products in their diet.

Potassium ranks seventh in order of abundance in the earth's crust. As rocks slowly disintegrate, potassium is released, but the rate of release is frequently too slow to provide the large amounts of this essential nutrient required by crops. Potassium fertilizers, mined and refined from naturally occurring deposits, are available to supplement soil potassium supplies so that crops can produce economically viable yields and soil fertility can be maintained.

In plants, animals and humans, potassium always occurs as a positive ion (K^+) in the liquid in every living cell. It is also found as the K^+ ion in soils, many rocks and seawater. Potassium ions are always balanced by an equal number of negative ions. For example, solid potassium chloride, KCl, when dissolved in water, dissociates (breaks apart) into equal numbers of K^+ and Cl^- (a negative ion).

In this booklet 'potassium' will be used when referring to the element, and 'potash' (K_2O, the oxide of potassium), when reference is made to the potassium content of fertilizers. For quick conversion, 1 kg K is equivalent to 1.2 kg K_2O.

Kemira

Potassium in plants, animals and humans

The importance of potassium to plants

Potassium has two roles in the functioning of plant cells. First, it has an irreplaceable part to play in the activation of enzymes which are fundamental to metabolic processes, especially the production of proteins and sugars. Only small amounts of potassium are required for this biochemical function.

Second, potassium is the "plant-preferred" ion for maintaining the water content and hence the turgor (rigidity) of each cell, a biophysical role. A large concentration of potassium in the cell sap (i.e. the liquid inside the cell) creates conditions that cause water to move into the cell (osmosis) through the porous cell wall (Box 1).

Turgid cells maintain the leaf's vigour so that photosynthesis proceeds efficiently.

Potassium is essential for growth and quality.

Box 1

Osmosis in plants

Osmosis is defined as the passage of water from a region where the concentration of salts is low through a semi-permeable membrane to a region where the concentration of salts is higher. In plants, water moves from cells with a low, to those with a higher, concentration of salts. This process is responsible for the movement of water within the plant and also the uptake of water from the soil by the roots. These conditions that lead to water movement are termed the 'osmotic potential'. Much of the potassium in the plant is in the liquid within the cell and its presence increases the salt concentration and thus controls the movement of water.

When plants take up water by osmosis their cells become gradually more turgid (swollen) until no more water can enter the cell. Turgidity is very important to plants because it maintains the rigid structure of most annual crops which do not have a woody structure of trunks and branches. In all plants, turgid leaves have a large surface area and this optimises the process of photosynthesis in the green chloroplasts in the cells.

Photosynthesis is the process by which plants harvest the energy of sunlight to produce sugars. These sugars contain carbon derived from the carbon dioxide in the air that has entered the leaf through the stomata, tiny openings mainly on the underside of the leaf. These tiny openings are surrounded by "guard cells" and it is only while they are turgid that the stomata remain open and carbon dioxide can pass through into the leaf. But most of the water transpired by the plant is lost through the stomata when they are open. Thus, if there is a water deficit, the plant needs to close the stomata to conserve water. The plant controls the opening /closing of the stomata by regulating the concentration of potassium in the guard cells. A large concentration of potassium ensures turgid cells and open stomata. When the potassium in the guard cells is lowered, they become limp and the stomata close.


K+S

Stomata (plant leaf pores)
natural size 0.055 mm

Potassium ensures the turgor, or rigidity of plant cells. While the guard cells surrounding the stomata are rigid the stomata remain open, allowing carbon dioxide to pass into the leaf where the carbon is converted to sugars.

A high osmotic potential in plant cells is also needed to ensure the movement through the plant of nutrients required for growth, and the sugars produced by photosynthesis, for example, the transport of sugar to grains, beet roots, tubers, and fruit. By maintaining the salt concentration in the cell sap, potassium helps plants combat the adverse effects of drought and frost damage and insect and disease attack. It also improves fruit quality (Box 2) and the oil content of many oil-producing crops.


BASF

Sugar beet well supplied with potassium has a large leaf area to produce sugars. Lack of potassium leads to severe wilting (as below).


PDA

Balanced fertilisation ensures that the plant has access to an adequate amount of each nutrient and is essential to optimise yields and, where appropriate, minimise environmental risk. Sufficient potassium also ensures that other inputs required to achieve optimum economic yields are used efficiently.
This applies especially to the use of nitrogen (Box 3).

With an adequate potassium supply, increased yields with nitrogen are accompanied by larger amounts of nitrogen in the crops and thus smaller residues of nitrate in the soil at harvest at risk to loss.

Plant roots take up potassium from the water in the soil (the soil solution) when growing vigorously. A rapidly growing cereal crop will take up as much as 6 kg K per hectare per day (ha, i.e. 10,000 m^2) (Box 4), and sugar beet even more, up to 8 kg K per ha. If this rate of uptake is to be maintained, the potassium in the soil solution has to be replenished quickly, which is only possible if the soil contains sufficient readily plant available reserves of potassium. Most of these reserves have accumulated from past applications of fertilizers and manures and they must be maintained by applying fertilizers or manures containing potassium.

Box 2

Effect of potassium on yield and quality of oranges

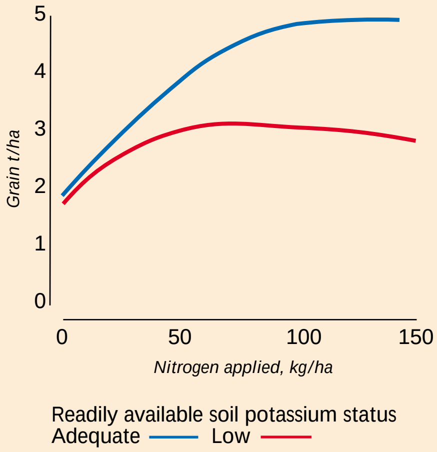
K_2O applied	Fruit weight	Yield	Juice	TSS [1]	Acidity	Vitamin C
g/tree	g	kg/tree	%	%	%	mg/100ml
0	165.2	31.9	46.3	9.77	0.549	52.8
200	173.1	36.2	47.2	9.89	0.542	54.1
400	178.0	37.5	47.2	10.06	0.533	55.9

[1] *TSS – total soluble solids*
(personal communication from Desai et al., 1986)

Box 3

Plant available potassium and the uptake of nitrogen

Adequate amounts of potassium must be readily available in the soil for plant uptake to maintain cell turgor and efficient photosynthesis. If there is not sufficient potassium, nitrogen will be used inefficiently, as shown by the yields of spring barley.

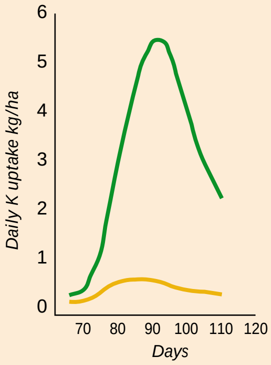


With too little readily plant available potassium in the soil, it was only justified to apply 50 kg nitrogen per hectare (kg N/ha) but with adequate potassium, 100 kg N/ha gave the optimum yield.

When nitrogen does not increase yield because of lack of potassium, the excess nitrogen remains in the soil after harvest as nitrate, at risk to loss.

Box 4

Pattern of potassium uptake by spring barley and its effect on grain yield



Daily uptake rate of potassium by spring barley in a field experiment on soil well (green line) and poorly (orange line) supplied with plant available potassium.

As a crop grows and increases in size, the daily requirement for potassium increases to reach a peak before gradually declining as the crop matures. For example, spring barley well supplied with potassium took up about 6 kg K/ha each day (green line) at the period of maximum uptake, whereas a crop grown with little readily available soil potassium (orange line) could only take up about 0.5 kg K/ha at the maximum uptake rate. The crop well supplied with potassium produced 4.9 t/ha grain and 2.6 t/ha straw, while on the impoverished soil the yields were 3.1 t/ha grain and 1.1 t/ha straw.

Potassium in the human diet

Humans and animals need to obtain an adequate supply of potassium from their food and feed to be healthy and grow normally. The source of this potassium is plants.

In the human body, most of the potassium is within the cells which contain about 98% of the 120 grams of potassium in the average healthy adult. As in plants, the potassium ions help maintain the osmotic equilibrium and take part in life-maintaining processes such as nerve impulses, muscle activity, heartbeat and the activation of enzymes in various metabolic processes.

Adequate potassium in our food is essential for health and growth.

Humans require both potassium, from food, and sodium, mostly from added table salt (NaCl). In healthy bodies the ratio of potassium to sodium should ideally be 2:1. In cooking or canning foods potassium is often depleted, because it is lost in the liquid, while sodium is often added. It is well recognised nowadays that people in many countries consume too much table salt[1] and this adversely affects the ratio of potassium to sodium.

A high sodium intake together with a low potassium intake influences vascular volume and tends to elevate blood pressure.

Consuming plant products rich in potassium especially those that are consumed raw like fruits, particularly bananas, and milk and fruit juices redresses the balance. It is possible to calculate the proportion of the daily potassium intake that is met by different foods (Box 5). For example, a medium sized banana contains 0.4 grams potassium, about 11% of the suggested daily intake, while a medium-sized potato will supply 21%.

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[1] The European Commission in its ‘Eurodiet’ report recommends a value of less than 6 g/day salt intake.

Potassium in drinking water

The potassium content of drinking water varies greatly depending on its source. It tends to be larger in mineral and spa waters than ordinary tap water. However, on average, the daily water consumption by adults supplies less than 0.1% of their potassium intake. But tap water is also used to make beverages like tea, coffee, beer and wines. The average total potassium intake in beverages can supply about 13% of the total daily intake of adults.

In recognition that potassium in drinking water poses no risk to human health, the European Commission has removed the limits it set on the allowable potassium concentration in drinking water from December 2003.

Box 5

Potassium requirements and content in food

As potassium is found in all living cells, the recommended daily intake varies with age:

Age in years	Recommended daily K intake in grams
0-3	0.8
4-6	1.1
7-10	2.0
11-14	3.1
15 onwards	3.5

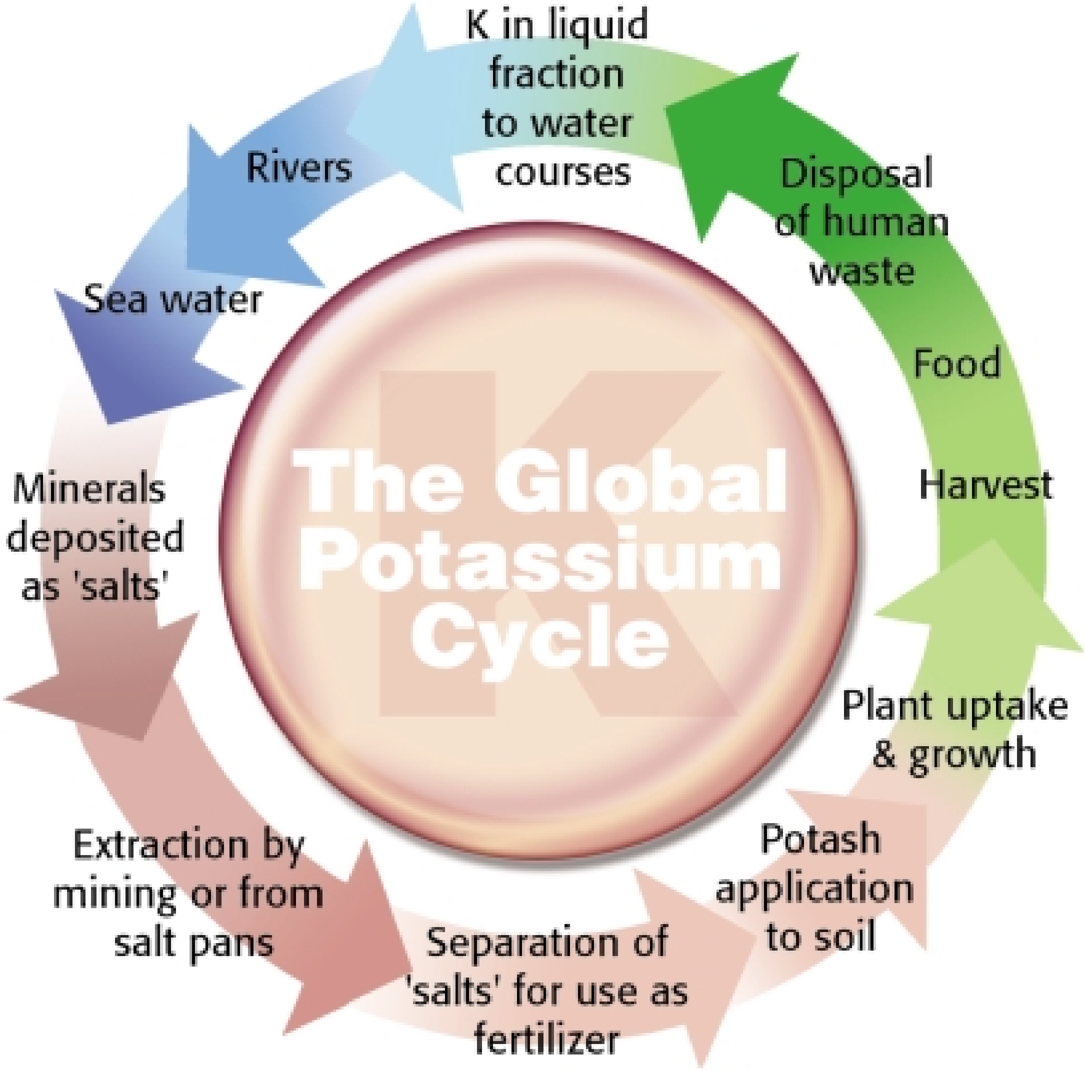
Data from Livsmedelsverket, Sweden (http://www.slv.se)

The average potassium content of some crop products:

	Product	Grams K per kg fresh weight*
Fruits	Banana	3.7
	Plum	3.0
	Apricot	2.8
	Orange	2.0
	Grape/strawberry	1.6
	Apple	1.1
Vegetables	Spinach	4.7
	Potato	4.1
	Carrot/celery	3.4
	Tomato	2.4
	Lettuce/cucumber	1.6
Beverages**	Milk/fruit juices	1.6
	Coffee	0.9
	White wine	0.8
	Light beer	0.4

* *These are only average values and there can be a wide range.*

** *per litre for beverages*


K in liquid fraction to water courses
Disposal of human waste
Food
Harvest
Plant uptake & growth
Potash application to soil
Separation of 'salts' for use as fertilizer
Extraction by mining or from salt pans
Minerals deposited as 'salts'
Sea water
Rivers
The Global Potassium Cycle
K

Potassium in nature and its use to man

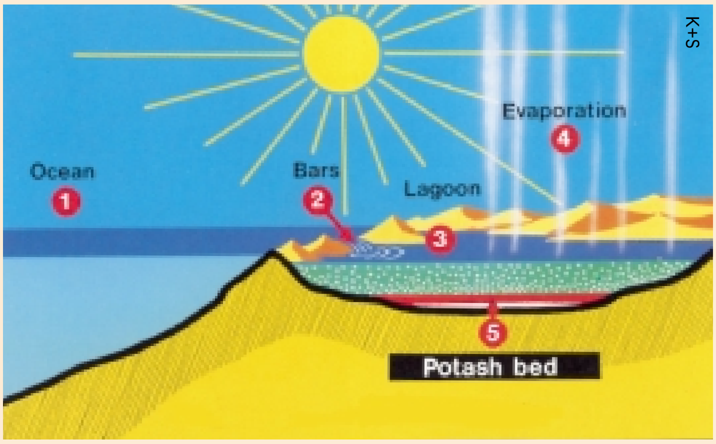
Potassium is a common element, about seventh in order of abundance in the earth's crust. Although it is widely distributed in many rocks, its concentration is small. However, there are salt deposits that are sufficiently rich in potassium for extraction to be commercially viable. These deposits, which were laid down hundreds of millions of years ago (Box 6), are often complex mixtures of salts, containing potassium, sodium and magnesium.

In the global cycling of potassium, it is first mined from the naturally occurring deposits and is refined by simple processes. As potassium fertilizer, it is applied to agricultural soils, taken up by plants, and enters the human food chain. It is then transferred to sewage treatment works and, because it is almost entirely soluble in water, is discharged in the effluent to water courses and from there back to the sea. So, using potassium fertilizers is not destroying a natural resource. Rather the use of potassium in agriculture is part of a very long global cycle.

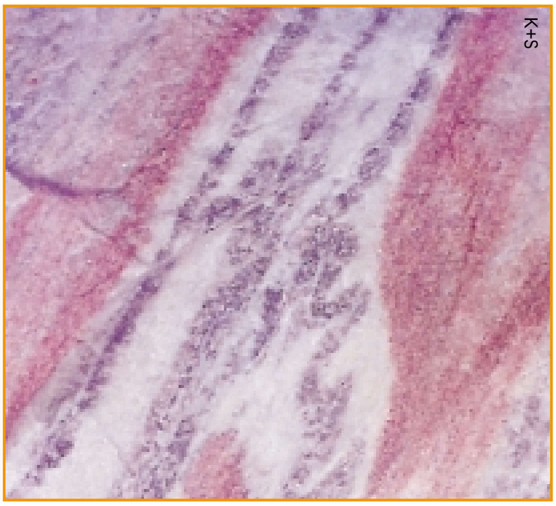
Potassium salts are products of nature. They can have a variety of colours caused by the trapping of tiny quantities of impurities, such as clay and iron compounds, as the deposits were laid down. The crude ore must be processed for a number of reasons. For example, transporting only refined potassium chloride (muriate of potash) is more environment friendly and cost effective. Also with a known potassium concentration in a fertilizer it is easier to calculate the amount needed to supply the quantity of potassium required by the crop.

Box 6

The formation of potash deposits



Salt deposits were formed in hot, dry climates hundreds of millions of years ago. Sea water enriched with salts was trapped in large lagoons (3) cut off from the ocean (1) by low rocks or sandbanks (bars) (2) over which the sea could flow to replace the water lost by evaporation (4) from the lagoon. As the water evaporated, the salts crystallised out and over many centuries salt deposits (5), often many metres deep, were formed. Subsequent major upheavals in the earth's crust buried these deposits deep below the current surface of the earth.

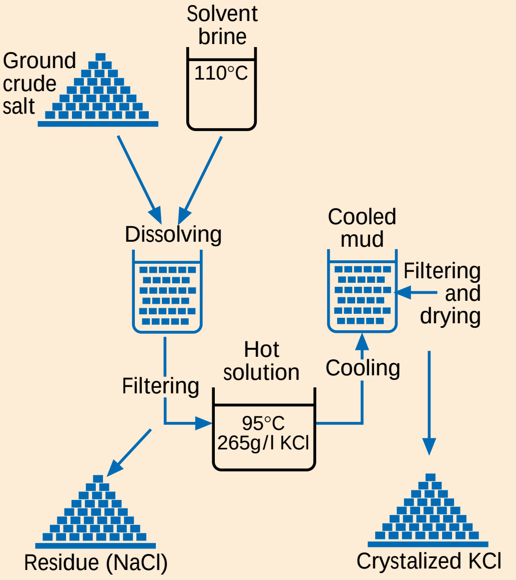


Strongly folded seams of sylvinite (KCl), halite (NaCl), kieserite ($MgSO_4$-H_2O) and carnallite ($KCl \cdot MgCl_2$-6 H_2O) as found in some potash mines.

Box 7

Separating the components of mined potash salts

The different components of the mined potash salts have to be separated to produce fertilizers of the required composition. Three methods are commonly used: thermal dissolution, flotation and electrostatic beneficiation. In the widely used dissolution process (see diagram) the finely ground, crude salts (mainly sodium and potassium chlorides) are added to a hot, sodium chloride saturated solution. Only the potassium chloride dissolves in this solution and the sodium chloride and other salts can be removed by filtration. The hot, potassium chloride rich solution is passed into vacuum coolers where the potassium chloride crystallizes, and is then removed and dried.



The techniques used to produce pure potassium chloride from the ore are simple and involve no chemical reactions (Box 7).

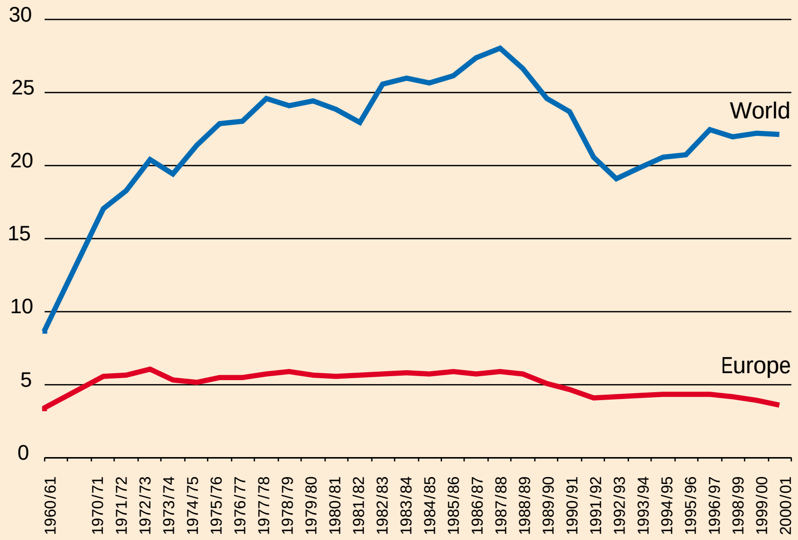
Potassium-bearing deposits are found in a number of regions throughout the world. The first to be discovered in Europe were those in Germany in 1856 and commercial exploitation of this ore started in 1861 at Stassfurt.

By 1959-60, world total production of primary potash product was about 8 million tonnes (Mt) K_2O. This had increased to some 25.5 Mt by 2000. Not all of this is used for potash fertilizer production.

The six main potassium producing countries are Canada, the Russian Federation, Belarus, Germany, Israel and Jordan (Box 8), with smaller production elsewhere. In Europe, for example, the UK produces 0.6 Mt and Spain, 0.5 Mt. The underground deposits are usually mined by means of conventional solid mining techniques.

In Israel and Jordan the potassium and other salts are extracted from the water of the Dead Sea by allowing the saline water to evaporate in shallow ponds. As the salts crystallise out

Consumption of potash fertilizer in the world and West Europe



Box 8

The world's major producers of potash*

(million tonnes K_2O)

	2000
Canada	9.17
Russian Federation	3.72
Belarus	3.37
Germany	3.15
Israel	1.75
Jordan	1.16
Others	3.22
World	25.54

**All grades, primary products. Data from FAO Yearbooks*

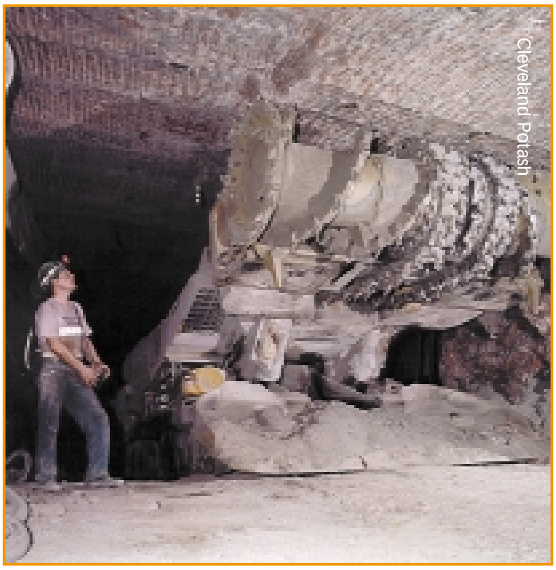
they are harvested for refining.

Solution mining is practised at a few locations in Canada and the USA. Water is pumped down into the ore and the salts in solution are brought to the surface for processing.

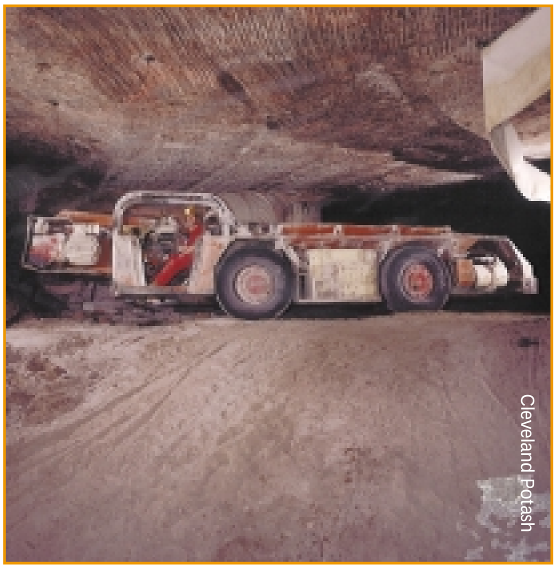
Reserves and resources of potassium

As with any naturally occurring material, consumption should be considered in relation to the known reserves and resources of that material. Reserves are generally considered to be deposits that can be currently exploited in an economically viable way, while resources (or potential reserves) are deposits that could be used if there were advances in processing technology or the finished product became more valuable.

It is not easy to estimate total global reserves. Current estimates of known, high quality reserves of potassium ore range from 9 to 20 billion tonnes K_2O. According to the lowest estimate, and at the current rate of consumption, this supply could last some 350 years. Total resources are estimated to be about 150 billion tonnes K_2O, which will last many millennia.



Cleveland Potash



Cleveland Potash

Modern solid mining techniques grind away at the rock face to produce coarse particles which can be transported to the surface.

The main uses of potassium

Today, some 95% of the total potassium output is used as fertilizer. Plant and wood ashes containing potassium carbonate were used for making soap and glass in antiquity and small amounts of potassium salts are still used for this purpose today.

In glass making, potassium gives a hard, heat resistant glass. There is a range of other minor industrial applications.

Potential uses include (i) water softening, to replace calcium and magnesium salts that make water “hard” and (ii) as a de-icer. Using potassium salts for these two purposes would be more expensive than the alternatives, but the wastewater would contain a valuable plant nutrient.

Potassium in agriculture

Applying farmyard manure to cropped land and spreading wood ashes were observed to improve crop growth many centuries ago. As early as 1750, when William Ellis was writing about English farming, he mentioned a potash kiln in which ashes were made from bean straw and these were sold to spread on grassland. Subsequently, wood ashes were extracted with water and the solution evaporated to produce a mixture of potassium salts. These supplies, most of which came from Russia or North America, were limited, however. It was not until the naturally occurring salt deposits at Stassfurt, Germany came into production in 1861 that potassium became more readily available in Europe. (The historical aspects of plant nutrition are briefly discussed in Box 9).

At the beginning of the 20th century, little potassium was used in agriculture. At that time, the yields of many crops were small by current standards and their requirement for potassium was met from the reserves of plant available potassium in the soil. Gradually, farmers became aware of the need to apply phosphate and potash. By the 1930s, more phosphate and potash than nitrogen was applied in fertilizers to arable land in Europe. For example, in the six countries, Belgium, Denmark, France, Great Britain, Germany and the Netherlands, the average amounts applied per hectare to arable land were 29 kg N, 43 kg P_2O_5 and 38 kg K_20 per ha, a ratio of 100 : 148 : 131. At the beginning of this century, such had been the increase in the yield potential of many crops that the average rates of application across the same six countries were 119 kg N, 39 kg P_2O_5 and 75 kg K_2O, a ratio of 100 : 33 : 63.

As yields have increased, the total amount of nutrients removed with the harvested produce has also increased (Box 10). If the productive capacity of the soil - its fertility - is not to decrease then nutrients such as potassium and phosphorus removed from the field in the harvested crop must be replaced. Farmers can calculate the amount removed based on the yield of the crop and its average potassium content, taken from published tables. The nutrient balance (nutrient applied minus nutrient removed) can then be calculated to see whether soil potassium is being enriched or depleted.


LEMKEN

With high yields, more nutrients are removed at harvest and have to be replaced.

Box 9

Historical Aspects of Plant Nutrition

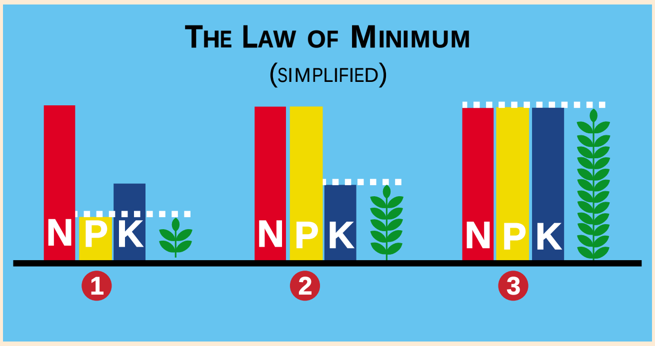
Mankind began to live in settled communities and cultivate the soil to grow food crops some 10,000 years ago. But it is less than 200 years since the results of field experiments began to identify plant nutrients and rank them in order of importance.

In the early 1800s in Switzerland, Theodore de Saussure showed that plants acquire their carbon from the carbon dioxide in the air and, from the soil, the mineral elements like phosphorus, potassium, calcium, magnesium, and silicon found in plant ash. The latter he deduced were taken up by the roots from the soil. Then, in the 1840s, Jean Baptiste Boussingault began a series of experiments on his farm in Alsace and by careful analysis of the crops and manures drew up a nutrient balance sheet for the crops grown in rotation. Little note, however, was taken of either of these studies and there was still uncertainty about the source of nitrogen for plants. All this changed in 1840 when Justus von Liebig, a German chemist, submitted his report, “Chemistry in its Application to Agriculture and Physiology” to the British Association for the Advancement of Science. This report set in train the notion that careful experiments and good analytical data are needed to understand plant nutrition. Liebig was held in such high regard that his report, published as a book, quickly went through several editions. He developed his thesis that “the crop on a field diminishes or increases in exact proportion to the diminution or increase of the mineral substances conveyed to it in manure”.

Besides stressing the importance of mineral nutrients, he went further, considering that nutrients need only be applied in the amount taken up by the crop. Based on this supposition, a range of products containing plant nutrients were prepared and sold as Liebig’s patent manure. However, Liebig was more a theoretician than an experimenter and his ideas, for example about patent manures and the source of nitrogen for plants were soon shown to be incorrect by the results of the field experiments started in 1843 by J. B. Lawes and J. H. Gilbert at Rothamsted.

Importantly, and building on the earlier (1830-1840) work of his compatriot, Carl Sprengel, Liebig enunciated what became known later as the “Law of the Minimum”. This law can be illustrated for three nutrients, nitrogen, phosphorus and potassium as follows:

In the first case ① there is sufficient nitrogen (N) and potassium (K) available but too little phosphorus (P). When this deficiency is corrected by applying an adequate amount of phosphorus ②, potassium becomes limiting. When potassium deficiency is corrected, the optimum yield is obtained ③. In a similar way, once a deficiency of any other nutrient has been identified it must be corrected to achieve the maximum benefit of all the other nutrients.



Inputs of potassium to agriculture

Wood ashes were originally used to supplement the potassium released by weathering of potassium-bearing minerals in the soil. As animal production increased, nitrogen, phosphorus and potassium were brought onto the farm in animal feeds. It has been estimated that in the 1930s, Great Britain imported in feed three times as much nitrogen, about the same amount of potassium and about two-thirds as much phosphorus as was used in fertilizers. As most farms at that time were mixed farms with animals and arable crops, much of the potassium and phosphorus in the feed were returned to the land growing arable crops in the form of farmyard manure. Today, since farms tend to specialise in crop or animal husbandry, many have no animals and arable farmers must consider the use of potassium fertilizers. Where animals are kept, they retain little of the potassium they ingest, so it is excreted in their dung and urine. This is evident in urine patches in grazed fields where there is lush growth. Slurries and organic manures produced by housed animals can be applied more evenly to land but they invariably contain only small concentrations of potassium. The amount of potassium in the manure will depend on the animal, its diet, and the way the excreta is handled. Most of the potassium will be immediately available to the crop, but it must be applied at the correct time. This will avoid any risk from pathogens the manure might contain, and the loss of nitrogen to the environment.

Sewage sludge (biosolids) contains little or no potassium, so farmers applying sewage sludge to their land must use another source of potassium.

Box 10

The effect of increasing yields of arable crops on the offtake of potassium

The yields of winter wheat and potassium in the harvested crops grown on Broadbalk, Rothamsted 1852-1999. The amount of potassium applied each year, 108 kg K_2O/ha, has remained constant throughout, so until the 1970s, the potassium balance was positive and readily available potassium in soil increased. Since the 1970s, the potassium removed each year has slightly exceeded the amount applied.

Period	Yield, grain t/ha	Potassium offtake in grain plus straw, kg K_2O/ha
1852-1871	2.70	55
1966-1967	3.07	53
1970-1975	5.48	106
1991-1992	8.69	117
1998-1999	9.35	108


PDA

In grazed fields, lush growth develops in areas of potassium-enriched animal dung and urine.

Box 11

The components of some potash fertilizers.

Potassium chloride (muriate of potash) KCl	60% K_2O	
Potassium sulphate (sulphate of potash) K_2SO_4	50% K_2O	45% SO_3
Potassium nitrate (nitrate of potash) KNO_3	46% K_2O	13% N
Sylvinite (crude potassium salts)	21% K_2O	26% Na_2O
Kainit (crude potassium salts)	11% K_2O	27% Na_2O

On those farms where organic manures are available, it is in everyone's interest that the nutrients are recycled to land and fertilizer applications adjusted to allow for the nutrients returned. However, manures are bulky and contain only a small concentration of nutrient, so their transport over long distances is not cost effective. Besides the cost of transport, which may be more than the value of the same quantity of nutrients purchased as fertilizers, there can be other, less obvious burdens on the social infrastructure, such as increased road traffic.

Manures contain plant nutrients which should be returned to the land, but it is not cost effective to transport them over long distances.

Fertilizers which contain potassium

Today potassium is available in a range of fertilizers. Some contain only potassium, while others contain two or more nutrients (Box 11). Manufacturers often produce a variety of fertilizers containing nitrogen, phosphorus and potassium in different proportions to meet the needs of specific crops and to allow for different levels of plant available nutrients in the soil. There are 'compound' or 'complex' fertilizers, produced as granules, each containing all the nutrients stated to be in the fertilizer. For example, a 15:15:15 compound fertilizer will contain 15% N, 15% P_2O_5 and 15% K_2O in each granule. Blended fertilizers are a physical mixture of individual fertilizers in proportions that provide the required amount of each nutrient.

In today's mechanised agriculture it is essential that fertilizers can be spread accurately by machine so the fertilizer industry produces individual fertilizers and granules within a narrow size range which are sufficiently robust not to disintegrate during transport and spreading.

Potassium chloride (muriate of potash, MOP) accounts for about 95% of all potassium fertilizers used in agriculture because it is the cheapest per tonne and most widely obtainable. As fine crystals it can be readily incorporated into granular compound fertilizers or it can be compacted into suitable sized particles to be spread by machine or used in blends.

Potassium sulphate (sulphate of potash, SOP) is more expensive per tonne than muriate of potash, as it contains two nutrients, potassium and sulphur. It tends to be used for high value crops and those where it can be shown to improve the quality of the crop. It improves the burning quality of tobacco and it increases starch levels in potato tubers. Potassium sulphate can also be used to advantage for all crops grown on saline soils, which occur in arid and semi-arid areas.

Potassium nitrate also contains two nutrients, nitrogen as nitrate which is readily available to crops, and potassium.

Both potassium sulphate and potassium nitrate are used in fertigation systems, where nutrients are added to, and applied with, the irrigation water.

A number of fertilizer manufacturers produce speciality fertilizers in which the ratio of potassium to other plant nutrients is adjusted to meet the specific needs of certain crops or the fertilizer has certain desirable physical features.

Box 12

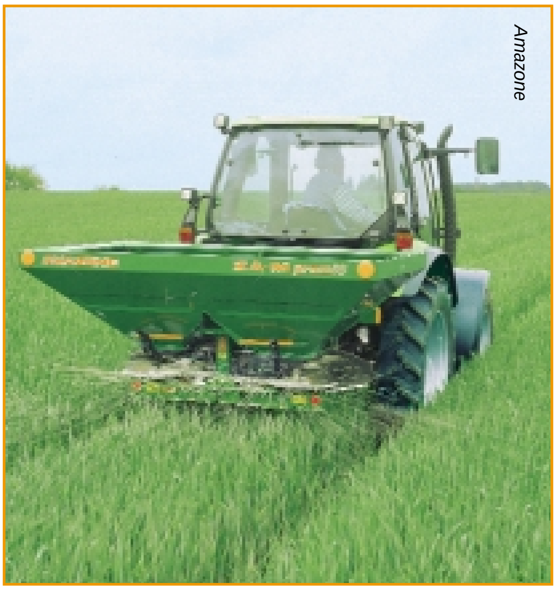
Accompanying anions in potash fertilizers

In all potash fertilizers, the K^+ ion is associated with a balancing anion : chloride (Cl^-) in muriate of potash, sulphate (SO_4^{2-}) in sulphate of potash, and nitrate (NO_3^-) in nitrate of potash. Each of these anions contains an essential plant nutrient.

It has been suggested in the UK that the chloride in muriate of potash (MOP) can be harmful to soil microbes. No factual evidence has ever been produced to support this, and the use of MOP over 150 years has shown no detrimental effects on the soil microbial population.

Application of potassium fertilizers

In West Europe, potassium fertilizer application peaked in 1979. Since then, it has declined by more than 40% to 3.8 million tonnes K_2O annually. In the European Union, the current average use of potash fertilizer on arable land equates to about 42 kg K_2O/ha and about 30 kg K_2O/ha on the Utilised Agricultural Area, which also includes grassland and permanent crops (Box 13).


Amazone

The number and proportion of plant nutrients in fertilizers can be varied to meet the needs of specific crops.

Box 13

Average application rates of potassium applied as mineral fertilizers to all crops on arable land and on the Utilised Agricultural Area (UAA) in West European countries, 2000/01.

	Average potassium application on: arable land, kg K_2O/ha	total UAA kg K_2O/ha
Austria	36	16
Belgium/Luxemburg	70	60
Denmark	33	32
Finland	31	40
France	41	37
Germany	46	34
Greece	20	7
Ireland	82	31
Italy	29	26
Netherlands	67	35
Norway	64	62
Portugal	32	11
Spain	35	21
Sweden	22	20
Switzerland	80	30
United Kingdom	54	23
EU	39	27

Using potassium efficiently

The use of potassium fertilizers is not an issue giving rise to concern, for two main reasons. First, there are no known adverse environmental effects, direct or indirect, from applying potassium fertilizers to agricultural land.

Second, there are such large reserves of potassium-bearing ores that there is no risk of shortage even in the far distant future.

This is in stark contrast to the other two major plant nutrients, nitrogen and phosphorus. If used inappropriately both can create environmental problems. Nevertheless, using excess potassium is an irresponsible use of a resource and an unnecessary financial cost to the farmer.

Potassium and soil

To increase the efficiency with which fertilizers are used in crop production, it is important to understand the relationships between soil nutrient reserves, soil texture and root growth.

Plant nutrition

In human nutrition the focus is on proteins, starch, sugar, fibre, vitamins and minerals. These are either manufactured by plants or, as in the case of minerals, taken up by plants from the soil. As humans, we acquire these various food items from plants and animal products. Plant nutrition, however, is considered in terms of the individual elements required by the plant. These elements are numerous and include nitrogen, phosphorus, potassium, magnesium, carbon, sulphur and oxygen. Plant roots take up all nutrients from the soil solution apart from carbon, hydrogen and oxygen, which are acquired from the carbon dioxide in the air via the leaves and the water in the soil.

Soil physical properties and texture

Soil is a complex mixture of mineral particles, organic matter, water and air. The mineral particles come from the breakdown of rocks of which there are two main types. Igneous rocks were created as the molten lava below the surface of the earth cooled and solidified. Sedimentary rocks such as sandstones were formed from the products of weathering of igneous rocks in geological time scales. Sediments laid down under the sea were compressed to rock-like consistency and then raised above sea level in massive upheavals. Soils are produced as the parent rock weathers to various size particles. By convention, only particles less than 2mm are considered as soil, larger particles are classified as stones. Soil particles are called, in descending order of size, sand, fine sand, silt and clay.

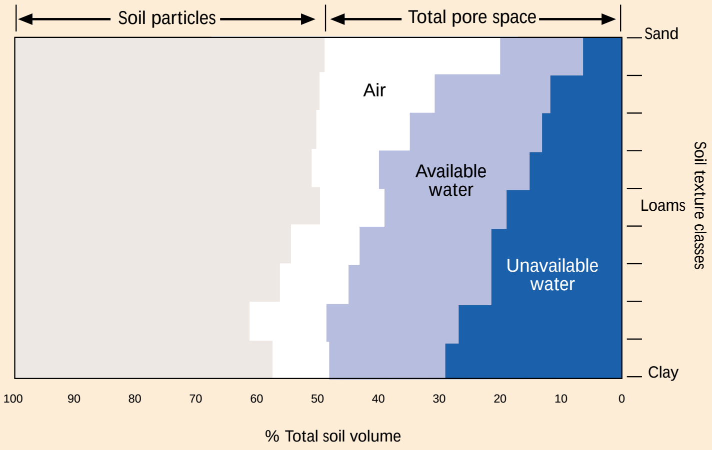
Soil texture depends on the ratio of the different sized particles in a soil and is classified descriptively as clayey (heavy) through loamy to sandy (light). The composition of sandy soils is predominately sand and fine sand, while clay soils contain mostly clay and silt.

Soil organic matter, humus, is a very complex natural material resulting from the breakdown of recently added fresh organic matter by soil microbes and earthworms. It plays an important role in developing and maintaining soil structure, in retaining water and as a source of plant nutrients.

In many soils, the mineral particles are held together by various mechanisms to form aggregates or crumbs. Within the crumbs and between them are spaces (pores) and a well-structured soil has many interconnecting pores of different sizes. These pores can hold air or water (Box 14). The water contains plant nutrients in forms that are immediately available for uptake by plant roots. As plants take up nutrients from the water, the soil solution, the concentration decreases and, to make good this loss, either the root has to grow to where there is more nutrient or the nutrients move in the water towards the root by a process called diffusion. Because both air and water are essential for roots and soil microbes to function properly, it is important that the pores form interconnecting passageways from the soil surface deep into the soil. This allows the movement of air to replenish the oxygen supply for the roots and the soil microbes, and the removal of excess water in which roots could drown.

Box 14

Relation between soil particles and pore space in soils of different texture



This figure shows that there is little difference in the proportion of solid particles and total pore space in soils of different textures, but there are large and important variations in the proportion of pore space filled with air and available and unavailable water. These pores are important because both roots and soil microbes need air and water to live and function. When there are large cracks, fissures and even worm channels in soil, water drains through them very quickly but in the smaller pores of varying size, water is held by capillary forces (surface tension). The smaller the pore diameter, the more strongly is the water held.

Water retained in the smaller pores will drain very slowly and will move towards the root as it takes up water – hence it is called available water in the figure above. As the water moves towards the root it carries nutrients with it. But in the very narrow pores, of which there are many in heavy textured, clayey soils, water is held so strongly by capillary forces that it does not move towards the root and, as the pore diameter is too small for the root tip to enter to take up water, this water is unavailable to the crop. Nutrients in the unavailable water have to move through the water to the roots.

Plant root systems

Plants frequently have large root systems. A good crop of winter wheat, for example, will yield 10 tonnes per hectare (t/ha) of grain and 8 t/ha of straw. Although the root system may only weigh 1.5 t/ha dry weight, this will extend to 300,000 kilometres/ha. This is equal to about 100 metres of root for each plant. Roots grow along the pores or passageways in the soil but the root tip of a cereal plant cannot enter a pore less than about 0.05mm in diameter. So roots cannot grow into compacted soil and the only way that they can access nutrients is if these diffuse out of the very narrow pores fast enough to meet crop demand.

The behaviour of potassium in soil

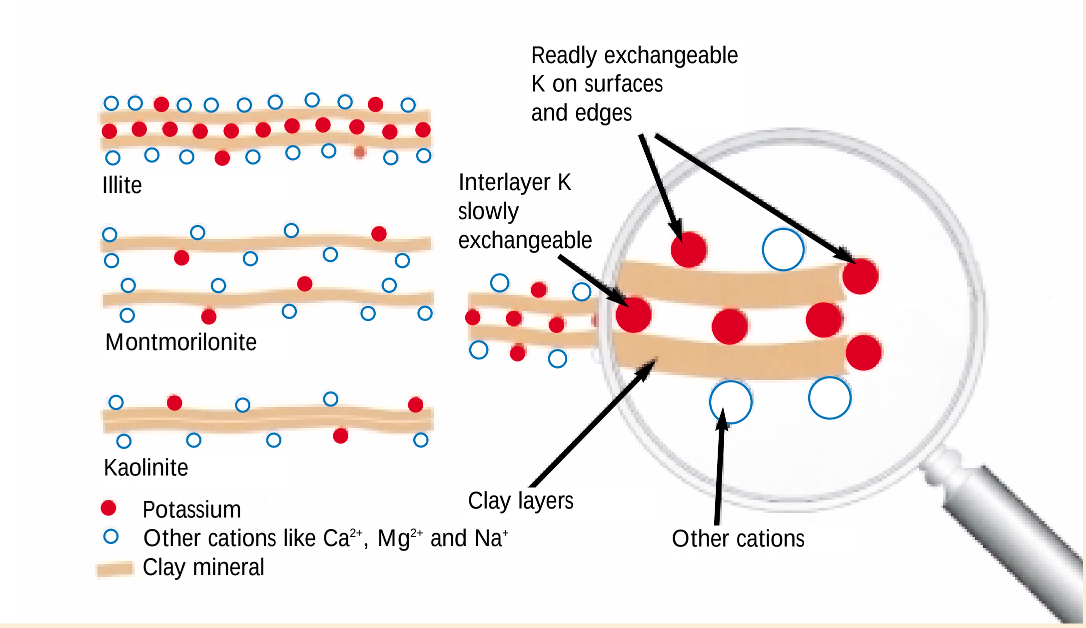
As rocks break down into the particles of sand, silt and clay that make up soil, potassium and other elements are released and may become available to plants.

The behaviour of the potassium in the soil is related to the type and amount of clay and soil organic matter. The type of clay depends on the parent rock, igneous or sedimentary, and the extent to which the mineral particles have undergone change (weathering) over many millennia. The clay-sized particles can be pictured as made up of many layers, each composed of interlocking silicon and oxygen atoms or aluminium and oxygen atoms. In some types of clay (illites) there are spaces between the layers into which positive ions, like potassium, can migrate and be held there by negative charges on the layers. In other clays (kaolinitic) the layers are so tightly compacted that ions like potassium cannot enter between them (Box 15). In both types of clay, potassium can be held at the edges of the clay layers. Also at the edges, the layers tend to open up, allowing ready ingress of potassium.

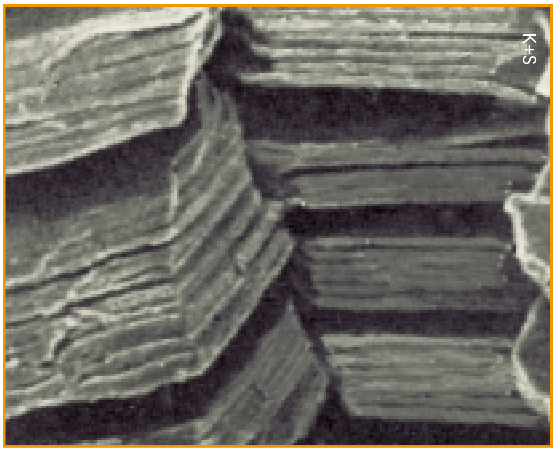
The positive potassium ions held at the edges of the clay layers and towards the outer edge of any interlayer space can be replaced relatively easily by other positively charged ions. When this occurs, the potassium is released into the soil solution from where it is taken up by plant roots. Potassium deeper in the interlayer space can only exchange slowly. The reverse process occurs when the concentration of potassium in the soil solution is increased by the addition of fertilizers and manures. In this way, reserves of potassium can be built up in those soils where there is separation between the layers that form the clay particle.

Box 15

Potassium and clay minerals



Clay minerals consist of lattices and layers and cations are held in various positions in and around the layers.



Close-up of an expanded clay mineral with the capacity to retain potassium in its interlayers (approximate magnification x 10,000).

Soil potassium and its availability to plants

Potassium in soil can be thought of as existing in four “pools” related to its availability to plants. These pools are the soil solution, where it is immediately available for uptake by roots, the readily available pool, the slowly available pool and the soil minerals, where it is least available (Box 16). As plant roots take up potassium, it moves through the pools from right to left. When more potassium is added in manures and fertilizers than is used by the crop, potassium ions move from the soil solution to the readily available and slowly available pools. This reversible transfer of potassium between these pools is very important in crop nutrition and soil fertility. In many soils, although only a small proportion of the potassium from each application of fertilizer or manure may remain in the readily available pool, the amount and thus the availability of potassium, increases as the quantity applied increases. There are, however, some soils where the concentration of readily available potassium changes little when large amounts of potassium are added or, more commonly, are removed. The difference in behaviour of these two groups of soil has not yet been fully explained.

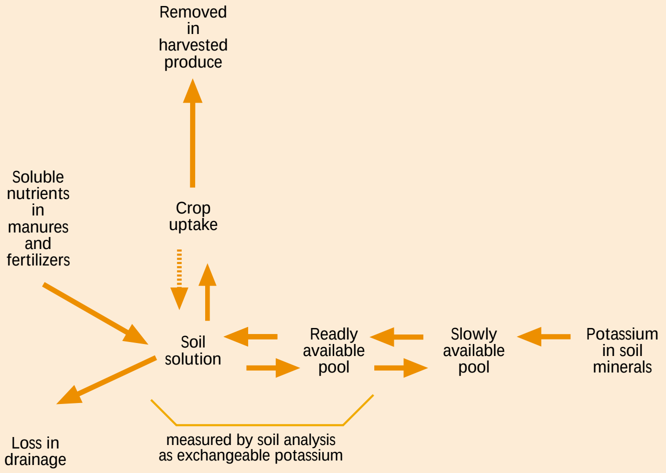
Studies have shown that building up readily available potassium reserves in soil ensures the best opportunity for crops to achieve their optimum economic yield. Adding large amounts of potassium fertilizer to soil with little readily available potassium, will not always increase yields to equal those in enriched soil (Box 17). This is because in enriched soil, the potassium reserves are uniformly distributed throughout the layer of soil in which most of the roots grow. As potassium in the soil solution is depleted by crop uptake, it is rapidly replenished from the reserves. The benefits are often greater with those crops that have a short growing season. Such crops do not have very extensive root systems and they must acquire nutrients quickly to optimise growth.

Although arable crops vary in their responsiveness to potassium (Box 17), it is essential to maintain adequate reserves in the soil to ensure that there is sufficient for the most responsive crops. The importance of maintaining such reserves is even greater when arable crops are grown in rotation (and the straw removed) with grass or herbage legumes. The latter crops remove much potassium without their yields being greatly affected, but yields of following arable crops can be considerably decreased when much of the potassium removed in the herbage crops has not been replaced.

For each soil and farming system there will be an optimum level for soil potassium reserves. The application of potassium in manures and fertilizers should aim to maintain this level of reserves, which can be assessed by field experiments and soil analysis.

Box 16

The potassium cycle in the soil-plant system



This cycle can be represented as in the diagram, with soil potassium envisaged as occuring in four categories or pools distinguished by the availability of the potassium to plants.

The two pools measured by soil analysis are the soil solution and the readily available pool. This is frequently referred to as the exchangeable potassium because it is determined by exchanging available potassium ions with ammonium ions.

There are large differences in the amount of potassium in each pool depending on the soil type and the past history of cropping and fertilising. Invariably, there is least in the soil solution and the amount increases in the next three pools. For example, there can be 100 times more potassium in the slowly available pool than in the soil solution.

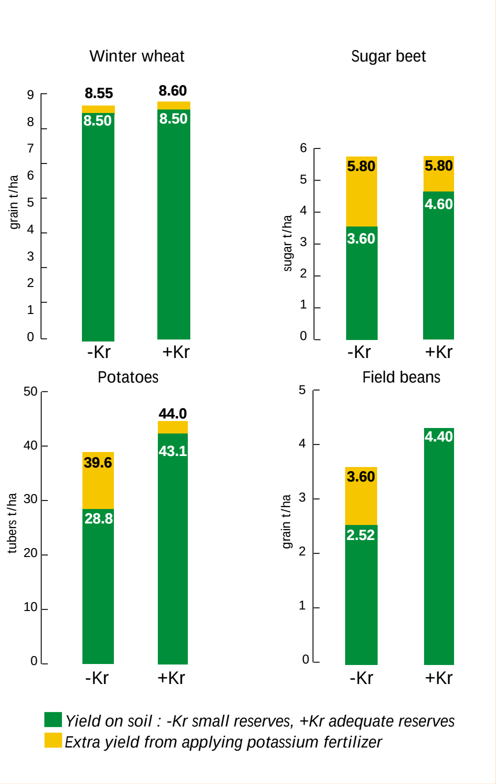
Box 17

Effect of adequate soil potassium reserves on the yields of four arable crops

The benefit of soil potassium reserves depends on the ability of the soil to release potassium and on the crop being grown. For example, deep rooted winter wheat with a long growing season, gave the same grain yield on a potassium-releasing soil at both levels of potassium reserves and only a small response to potassium fertilizer.

The yield of sugar from sugar beet was larger on a sandy soil with potassium reserves than on the soil without and potassium fertilizer increased the yield on the soil without reserves to equal that on the soil with reserves.

Potatoes and field beans (*Vicia faba*) planted and sown in the spring have a short growing season and yielded much less on the soil with small potassium reserves than on the soil with adequate reserves. Applying potassium fertilizer to the soil with small reserves did not increase yield of either crop to equal that on the soil with adequate potassium reserves.



Analysing soil for readily available potassium

Soil sampling, followed by laboratory analysis, assesses the soil nutrient status.

It is important to assess the quantity of potassium in the soil solution and the readily available pool (Box 16) to ascertain whether or not to apply potassium fertilizer. The soil is extracted with a solution containing a reagent that effectively displaces those K^+ ions, held on clay particles and soil organic matter, that could become available to plants during the growing season. After extraction, the soil and solution are separated and the potassium concentration in the solution is measured. The analytical results can be classified on a descriptive scale (very low, low, satisfactory, high) or a numerical scale (the analytical values are grouped and a number assigned to each group). Soil analysis should be used as the basis for recommending fertilizer applications.

Fertilizer recommendations

The efficiency with which plant nutrients are used by crops has been a concern of soil chemists and agronomists for a long time. As a consequence they have sought to refine fertilizer recommendations.

Fertilizer recommendations are based on the descriptive or numerical classification of soil, derived from its analysis which is, in turn, related to crop responses measured in field experiments (Box 18). Each experiment tests rates of added potash fertilizer to ascertain the optimum rate, and a number of experiments is done on soils with a range of readily available potassium. The response to freshly applied potash fertilizer will decrease as available soil potassium increases, so the fertilizer recommendation must be based on soil analysis.

Critical values for readily available soil potassium

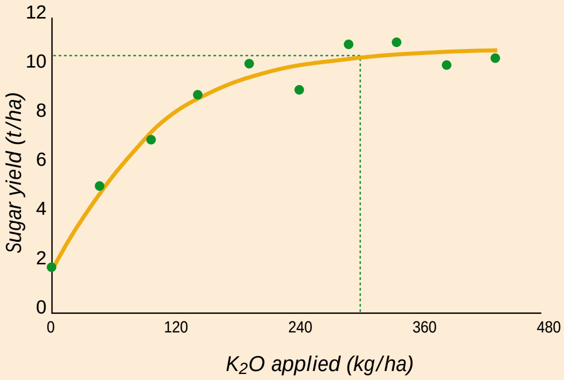
Another approach to potassium fertilizer recommendations is based on determining the critical level for readily available soil potassium in different soil types. This approach aims to ensure that reserves are not built up unnecessarily.

As readily available soil potassium increases so does yield, rapidly at first then more slowly until it levels off and reaches a plateau. The level of potassium required to produce yields close to the plateau can be considered as the critical value for that crop grown on that soil (Box 19). Below the critical level, yield is considerably less than it should be, resulting in a financial loss to the farmer.

For soils much above the critical value, where there is no increase in yield there is no financial justification for the farmer to apply more potassium fertilizer. So the rationale for potassium additions must be to maintain soils just about the critical level. Once this value has been reached, it should be maintained by replacing the potassium removed in the harvested crop. Periodic soil analysis will check whether applying this amount of potassium is maintaining the critical level in soil. This concept of maintenance or replacement applications is becoming well established among farmers and their advisors. It requires the estimation of nutrient balances and then adding as fertilizer the amount of potassium removed in the harvested crop. This ensures that potassium taken up from soil reserves is replaced, and soil fertility is not put at risk.

Box 18

The use of field experiments to produce fertilizer recommendations



To obtain a good relationship between yield and the nutrient under investigation, at least six amounts of the latter should be tested. The response curve is fitted statistically as in this example for sugar beet grown on a silty clay loam soil.

The data can be interpreted in two ways:

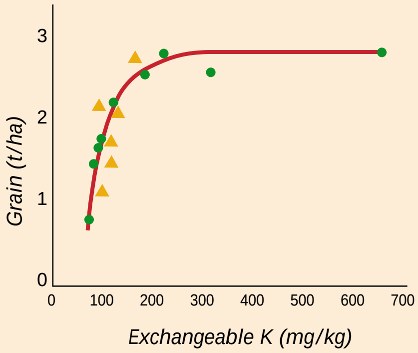
- The potassium required to achieve 95% of the maximum yield is estimated from the curve (the dotted line). In this example, the 95% yield was 10.4 t/ha sugar given by a little less than 300 kg K_2O/ha. So the recommendation would be to apply 300 kg K_2O/ha.
- The optimum economic rate of application can be estimated from the response curve. This is the amount of K_2O where the cost of adding one additional kg of K_2O is more than the value of the additional crop produced.

Box 19

Relating yield to soil nutrient status – critical values

The response of a crop to increasing levels of plant available potassium in soil can be determined by field experiments. Ideally, in one experiment, plots are established with a range of readily available soil potassium, and crop yield is measured and plotted against these values as illustrated in the figure.

In this field experiment, the critical readily available soil potassium (exchangeable K) for field beans (*Vicia faba*) was about 200 mg/kg.

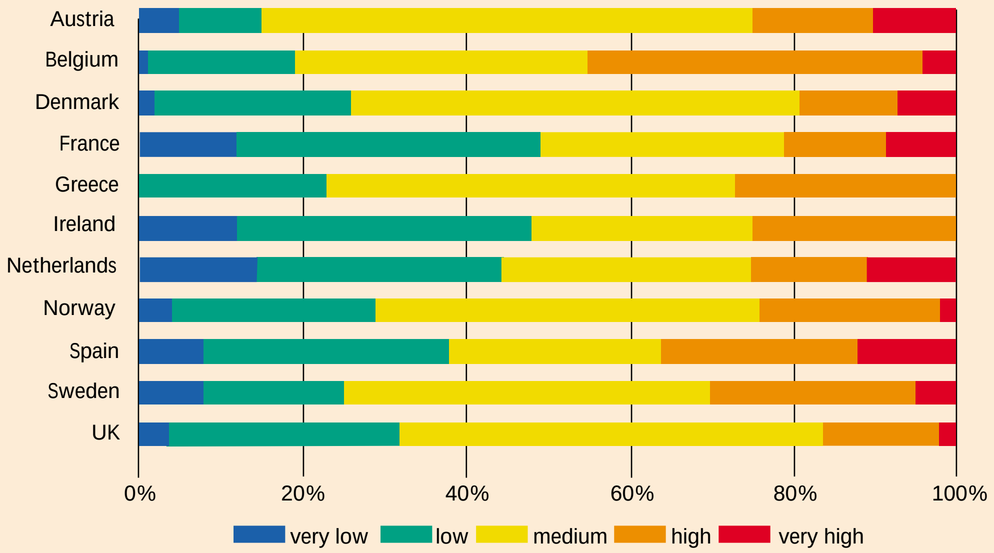


The potassium status of European soils, as estimated by routine soil analysis varies widely (Box 20). For many countries some 25% of soils test as very low and low in readily available potassium. Such soils require applications of significantly more potassium than that removed in the harvested crop to increase soil reserves and thus soil fertility. On soils with adequate potassium, applications need to sustain the potassium status. For soils with very high values, potassium applications can be omitted for a period of time and soil analysis will indicate when applications of potash fertilizers are needed again.

Plants growing on soil with too little available potassium may show visual symptoms of potassium deficiency. These are a useful guide but often they develop when it is too late to take remedial action for annual crops. However, visual symptoms indicate the need to sample and analyse the soil so that fertilizer can be applied before the next crop.

Box 20

Estimated National Potassium Status of European Soils



Source: Data from an EFMA survey

The importance of potassium should not be underestimated. These pictures show obvious signs of potassium deficiency in fodder beet and clover.

Potassium and some issues related to its use in agriculture

Movement of potassium in and from soil

There is no evidence that potassium has any adverse effects either in agriculture or in the wider environment. If potassium is lost from soil, then it is a financial loss to the farmer and farming practices should aim to minimise it.

It is only when excessive amounts of potassium are added and the capacity of the soil to retain potassium is exceeded, that there is any risk of appreciable amounts of potassium moving down through the soil when excess rainfall leads to drainage. There is much evidence to show that potassium moved from the surface soil will be retained in the subsoil if it contains appropriate clay minerals. Studies suggest that on soils other than very sandy ones, if they are not over enriched with potassium, then the amount of potassium that is leached is about 2-3 kg K/ha per year, with losses rarely exceeding 5 kg K/ha annually. Very sandy soil with little clay and organic matter retains little potassium.

Based on these facts, appropriate agronomic practices can be identified for different soils to optimise the utilisation of potassium and minimise movement. On light textured, shallow soils with little clay and soil organic matter, potassium should be applied annually and the amount adjusted to meet the needs of the crop. For spring-sown crops, the fertilizer should be applied just before seedbed preparation and preferably once there is no further risk of through drainage. Heavier textured, clayey soils, with a greater ability to retain potassium, are frequently used to grow autumn sown crops and potassium can be applied to the seedbed in autumn.

Potassium that has been leached from the surface soil and retained as plant available potassium in the subsoil, can be used by deep-rooted crops like winter wheat and sugar beet. This uptake of potassium from subsoils can affect the response of crops to surface applied potassium fertilizer. However, it is doubtful whether it would be cost effective to sample and analyse subsoils annually for available potassium because root proliferation in subsoils, even with deep-rooted crops, will vary considerably from year to year. Thus there will be great uncertainty and variability in the contribution of subsoil potassium to the total potassium needs of a crop and this would make it difficult to adjust potassium fertilizer recommendations.

Potassium and organic farming

Organic farming takes a holistic view to growing crops and animal husbandry. It aims to focus on ‘natural’ systems and to use renewable resources in preference to non renewable ones, as far as possible. As in conventional farming, the maintenance or improvement of soil fertility is a principle aim, as well as the recycling of animal manures. The latter implies that there are both animals and crops on organic farms.

Box 21

Potassium fertilizers permitted for use in organic farming

Extract from Annex II ‘Fertilizers and soil conditioners’ of Council Regulation (EEC) No 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs

Crude potassium salt (e.g. kainit, sylvinite, etc.)	Need recognised by the inspection body or inspection authority
Potassium sulphate, possibly containing magnesium salt	Product obtained from crude potassium salt by a physical extraction process, and containing possibly also magnesium salts Need recognised by the inspection body or inspection authority


IGER

Animal manures contain plant nutrients, including potassium, and applying them to land replaces some of the nutrients removed in the harvested crop

However, manures simply recycle. They do not introduce extra potassium to compensate for that removed from the farm in crop produce. Nutrients taken in by grazing animals go back in faeces and urine but on very limited and scattered areas that become over-enriched so that nutrients cannot be efficiently used by plants. Farmyard manure and slurry, collected while the animals are housed, can be spread more uniformly, but may not be sufficient to ensure that adequate amounts of nutrient are added to all fields.

Where animals are kept, extra potassium is often brought on to organic farms in purchased feedingstuffs and bedding materials. Again, such imports are discouraged and should mostly come from organically grown crops. In a recent survey of European farms, only intensive dairy farms purchasing large quantities of feedingstuffs had sizeable positive potassium balances.

The proponents of organic farming suggest that, because the availability of nitrogen restricts yields, less potassium is required. This is true when nitrogen, and not some other nutrient, is controlling yield. Some also suggest that if too much potassium is in the soil, plants will take it up unnecessarily. This is not so. Plants take up potassium to maintain the turgor of their cells. If water is available, they will take it up and will therefore require an appropriate amount of potassium. If extra yield is not produced as a result of the ready availability of water, then it can appear that the extra potassium serves no useful purpose, but this is not so.

These and other considerations appear to have led many in the organic farming movement to suggest that, where there is a shortfall in the potassium supply, whether recycled or brought in with feedingstuffs, it will be made good by the amount and rate of potassium released from plant available soil reserves. However, as potassium release and plant uptake from these sources continue, soil fertility is being depleted and this does not appear to be in keeping with the stated objectives of organic farming, namely to maintain or improve long term soil fertility.

Seemingly, as a last resort, if organic farmers can show that their yields are restricted by a lack of potassium they can apply to a recognised inspection body or authority to use either a crude potassium salt, such as kainit or sylvinite , or potassium sulphate (Box 21). The organic farmer will then be applying potassium in exactly the same form as the conventional farmer.

The external source of nitrogen for organic systems largely derives from the activities of bacteria that live symbiotically in the nodules on the roots of leguminous plants. They fix nitrogen from the soil atmosphere, getting their food from the plant. These bacteria need an ample supply of potassium to function efficiently. Many legumes are much more responsive to applied potassium than other plants because they have less extensive root systems and are less able to scavenge nutrients from the soil. So it is even more vital to maintain adequate available potassium reserves in soil supporting organic systems.

In all farming systems, there is another important reason for maintaining adequate levels of available potassium in soil.

Many fresh fruits and vegetables are a good source, often the only natural source, of potassium for humans. If the soil contains too little potassium to meet the plant's needs the potassium content in the crop will be less than optimum, with the risk that the daily human dietary intake may not be sufficient to replace natural losses.


Rothamsted Research

Bacteria that live in the nodules on the roots of leguminous plants need an ample supply of potassium to function efficiently and fix atmospheric nitrogen for the host plant.

Potassium in agriculture and the role of the fertilizer industry

The nutrient requirement of plants

Plants live, grow and reproduce by taking carbon dioxide from the air, energy from the sun, and water and mineral substances from the soil. Plants contain practically all (92) of the elements known to occur in nature but apparently not all are needed for their growth and function. Those that occur in very, very small amounts may play a role yet to be discovered. Currently, 16 of the elements are known to have a function in plants but the amounts required vary considerably.
Those that are needed in large amounts - nitrogen, phosphorus, potassium, calcium, magnesium and sulphur - are known as the major nutrients. The micronutrients, such as boron, manganese, molybdenum, copper and zinc are required in much smaller quantities.

When soils have been in cultivation for some years without the addition of the major nutrients, they will invariably be unable to supply sufficient for crops to produce optimum yields. To make good any deficiency in the soil supply that cannot be met by recycling through manures and other organic wastes, a wide range of fertilizers have been developed by the fertilizer industry over the past 150 years.

Potassium is an essential nutrient for all plants and it is required in large amounts. Grass, for example, often contains at least as much potassium as it does nitrogen. Although the clay minerals in some soils can release substantial amounts of potassium, the rate of release is rarely sufficient to meet the large quantity required to achieve the optimum yields that make a farm financially viable. The use of mineral fertilizers, including potassium fertilizers, has been one factor among many that has helped to assure food security in Europe. It is still important today to maintain the appropriate level of readily plant available potassium in soil to ensure adequate plant growth and healthy animals.


PDA

A good crop of field beans grown on soil with adequate potassium.

Changing concepts in the management of potassium in agriculture

From the late 1950s until the late 1980s, European governments actively promoted agricultural policies aimed at improving self-sufficiency in agricultural production. This invariably involved accepting the need to improve the productive capacity, i.e. the fertility of the soil. One priority was to raise the potassium status of the soil, because little potassium fertilizer had been available in most European countries during World War II. To achieve this, farmers were encouraged to be generous in the use of potassium fertilizers and, in consequence, soil potassium status was improved. Equally importantly during this period, crop varieties with a high yield potential were introduced, as were chemicals to control weeds, pests and diseases. As yields increased, there was both a need and a justification to increase the quantity of plant available nutrients in soil. As manures alone could not meet this need, farmers were right to use more fertilizers.

However, the increased use of nitrogen greatly outstripped that of potassium in particular, and phosphorus. It is important to recognise that there needs to be a balance between all three nutrients. The fertilizer industry totally supports the concept of balanced fertilisation which must be stressed to farmers and implemented by them.

About 15-20 years ago, a number of environmental issues relating to some agricultural practices began to emerge. These included the use of agro-chemical inputs used in most husbandry systems. Unfortunately, the role and function of the different inputs have not been well explained and are not always appreciated by the general public. This has led to confusion as to what can and cannot be replaced by appropriate alternatives. The unique role of each plant nutrient means that there is no alternative. Manufactured fertilizers containing phosphorus and potassium are derived from naturally occurring materials. Through simple chemical processes, they are transformed into easy to use products in which the nutrients are readily available to plants and can supplement the nutrient supply in the soil to achieve optimum economic yields. If used appropriately, they do not cause environmental damage.

Although there has been no concern about the use of potassium fertilizers, the fertilizer industry has been at the forefront in encouraging farmers to follow published Codes of Good Agricultural Practice in all aspects of husbandry, including the use of fertilizers. The industry has consistently and strongly advocated best nutrient management practices that seek to optimise yields while minimising any risk of adverse environmental impact. As farmers follow such guidelines they not only help to preserve the environment, but they also decrease the cost of food production.

One approach to achieving this goal is integrated plant nutrient management and balanced fertilisation.

Integrated plant nutrient management

Integrated Farm Management (IFM) has developed as an overall farming approach to conserve and enhance the environment while economically producing safe, wholesome food. It “balances food production, profitability, safety, animal welfare, social responsibility and environmental care”[2]. IFM demands a disciplined and balanced approach to production, including the prudent use of all inorganic and organic inputs, so that costs are

[2] From ‘A Common Codex for Integrated Farming’, published by the European Initiative for Sustainable Development in Agriculture,

contained while producing food to the required market specifications. It is a whole farm policy, following known principles and procedures, that will produce a farming system appropriate to each farm business.

The concept of integrated plant nutrient management (Box 22) and balanced fertilisation presents a great opportunity to optimise the use of all nutrient inputs on the farm. The practice is simple. Farmers must be encouraged to carefully consider both the amount of each nutrient, and the balance between nutrients, required to achieve the expected optimum yield. They must then assess all sources of each nutrient available on the farm in relation to the amount required. So, when manures are applied, allowance will be made for the immediate availability of the nutrients they contain when calculating the amount of fertilizer to apply. Once the critical value for soil potassium has been reached, the total application should equal the amount of potassium removed in the harvested crop. For soils that are below the critical value, the industry will continue to promote the need to add extra potassium to raise the soil to the critical value.

Box 22

Excerpt from ‘A Common Codex for Integrated Farming’, published by the European Initiative for Sustainable Development in Agriculture (EISA)

Crop Nutrition:

All crops remove nutrients from the soil and these must be replaced in an ecologically responsible way. Integrated Farming achieves this by a balanced application of organic and mineral fertilisers including, if useful, organic wastes and composts.

This requires:

- Detailed analysis of the nutrient status of the farm soils, repeated on a regular basis.
- Where appropriate, a planned cropping rotation to minimise nutrient loss (especially by leaching) and to make best use of natural restoration of fertility.
- Calculation of crop nutrition requirements and matching fertiliser applications accordingly (including analysis of the contribution by organic nutrients).
- Keeping soil pH at optimum levels through appropriate management.
- Taking qualified, professional advice.

Increasingly in Europe there is a need to understand the value of the environment in which our food production takes place. But such concerns must be balanced with the equally pressing need to ensure that successful farm businesses can produce an adequate supply of high quality food. IFM offers a practical way to achieve these objectives on an individual farm basis. It is more realistic than the approaches taken in organic farming and more responsive to the demands of society than unrestrained attempts to achieve maximum production.

The fertilizer industry fully supports and endorses the concept of integrated plant nutrient management as a valuable contribution to sustainable agriculture.

Sustainable use of fertilizers

The fertilizer industry is a relatively young industry. Commercial production of superphosphate started in London in 1843, the first European potash mine was opened in Germany in 1861 and it was not until the early years of the 20th century that industrial processes were developed to fix atmospheric nitrogen to make nitrogen fertilizers. Prior to the development of these industrial processes, supplementing plant nutrients in soil relied on recycling manures and limited supplies of products such as wood ashes, Chilean nitrate of soda and ammonium sulphate, a by-product of town gas manufacture.

Grass yields increased by adequate potassium (Plot F) compared with Plot A without potassium.

In the aftermath of the Second World War, fertilizer use in Europe increased, especially nitrogen. But this increase has not been sustained. In fact, in recent decades, consumption of not only potassium but also of nitrogen and phosphorus as mineral fertilizers has declined, and the industry forecasts that this trend will continue. As far as potassium is concerned, this will have an impact once slowly available soil reserves are used. It is essential to monitor soil potassium reserves so that they do not decline to the point where soil fertility, crop yields and quality are put at risk.

Box 23

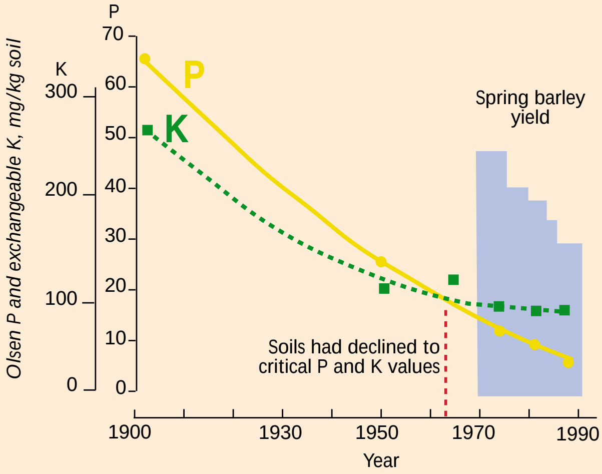
Long term effect of sub-optimal fertilizer applications on crop yield

In a long term field experiment at Rothamsted (UK), phosphate and potash fertilizers were applied annually, first to winter wheat and then to potatoes, from 1856 to 1901.

Yields were small and the large annual residue of both nutrients built up very large reserves of both readily available and slowly available phosphorus (P) and potassium (K).

Neither phosphate nor potash was applied after 1901, and the readily available pool of both declined slowly. It was not until the 1970s that the yields of spring barley began to decline because the readily available pool of both nutrients was below the critical value (Box 19).

In other soils with smaller reserves, readily available potassium will decline sooner to levels at which there will be an appreciable loss of yield.



In recent decades, the fertilizer industry has developed a wide range of products with compositions adjusted to more accurately meet the nutrient requirements of crops. Of equal importance, have been the greatly improved physical properties of fertilizers so that they can be applied with accuracy.

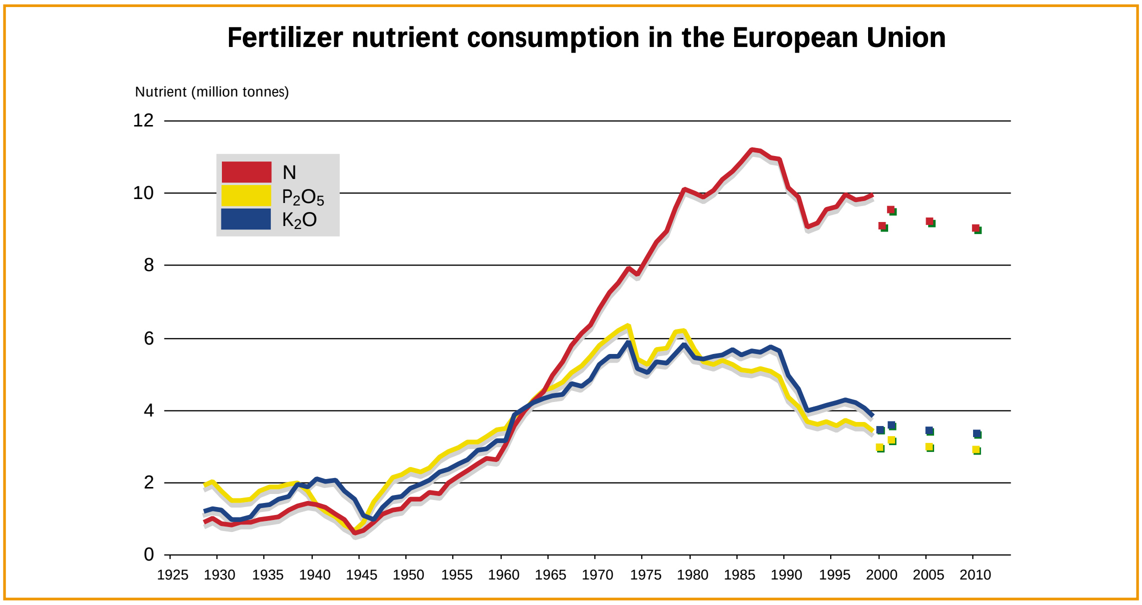
In co-operation with research institutes, universities, government departments and agencies and national and other extension services, the West European fertilizer industry has taken an active role in promoting the efficient use of fertilizers. It has, for example, instigated research and development leading to new and improved fertilizer recommendations, now frequently based on soil analysis and computer programmes. As concerns have been voiced about sustainable agriculture and issues raised about the impact of fertilizer use on the environment, the industry has responded by encouraging tailor-made, site specific recommendations for on-farm nutrient management and the development of precision farming.

New and improved fertilizer recommendations are now frequently based on soil analysis and computer programmes.

The fertilizer industry supports good agricultural practice in the use of organic manures, including their immediate incorporation to minimise nitrogen losses

The West European fertilizer industry fully supports proposals for calculating nutrient balances at the farm level. In some European countries, determining nutrient balances is already a requirement and at some stage it could be introduced in others. Such systems require a farmer to keep accurate records of the nutrients applied and removed in the harvested crop. This provides evidence that the size of the nutrient balance does not exceed the limit set for each nutrient. Currently limits are set for nitrogen and/or phosphorus because excessive use of these nutrients can lead to adverse environmental effects.

Such concerns do not apply to potassium because it is not known to have any undesirable impact on the environment. Nevertheless, the fertilizer industry urges farmers to adopt the nutrient balance approach to the use of potassium too. This would prevent a reduction in both soil fertility, through applying too little potassium, and an economic disadvantage through over-use.



Source EFMA

There is a downward trend in mineral fertilizer use, due to improved nutrient management on farms and the assimilation of more organic waste in farmers' nutrient balances

Although fertilizers are more easily managed and can be applied with greater accuracy than manures, the West European fertilizer industry recognises the need for both, and totally supports the concept of integrated plant nutrient management. To use both sources of nutrients successfully, farmers need sound advice based on the results from reliable field experiments.

Studies show that when such advice is available most arable farmers do use fertilizers according to recommendations. However, in animal husbandry, the value of the nutrients contained in manure is difficult to assess and, in consequence, allowance has not always been made for them.

The West European fertilizer industry has accepted, and continues to accept, the challenge to provide farmers with fertilizers of the required chemical composition and physical quality so that their use contributes to the financial viability of the farm and sustainable agricultural practices whilst minimising any negative impact on the environment from the manufacture and use of the industry’s products.

The use of mineral fertilizers, including potassium fertilizers, has been one factor among others that has helped to assure improving food security in Europe.

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